

WHAT IS CLAIMED IS:

1 1. A radio base station apparatus provided with an array  
2 antenna having a plurality of antenna elements, comprising:  
3 a probe signal adding unit which adds a probe signal to each  
4 of receive signals received by said plurality of antenna elements;  
5 a probe signal extracting unit which extracts the probe signal  
6 from said receive signals added with the probe signal;  
7 a phase calibration calculation unit which calculates phase  
8 calibration required for calibrating a phase of each receive signal  
9 based on the probe signal extracted by said probe signal extracting  
10 unit; and  
11 a phase calibration unit for calibrating said phase of the each  
12 receive signal based on the phase calibration from said phase  
13 calibration calculation unit.

1 2. The radio base station apparatus according to Claim 1,  
2 wherein:  
3 said probe signal extracting unit comprises a despreading  
4 unit which despreads the receive signals added with said probe signal  
5 to extract said probe signal.

1 3. The radio base station apparatus according to Claim 2,  
2 wherein:  
3 said probe signal adding unit comprises:  
4 a probe signal generating unit which spreads probe data with

5 a predetermined spread code to generate the probe signal;  
6 a conversion unit which converts said probe signal to a radio  
7 signal; and  
8 a coupling unit which couples the probe signal converted to  
9 said radio signal and said receive signals; and  
10 said despreading unit performs despreading on signals  
11 outputted from said coupling unit, using the same spread code used  
12 in said probe signal generating unit, in order to extract the probe  
13 data; and  
14 said phase calibration calculation unit calculates the phase  
15 calibration required for calibrating the phase of each receive signal  
16 based on the probe data extracted by said despreading unit.

1 4. The radio base station apparatus according to Claim 3,  
2 wherein:  
3 said phase calibration calculation unit compares the probe  
4 data extracted by said despreading unit and the original probe data  
5 inputted to said probe signal generating unit, calculates quantity of  
6 distortion given to the probe data extracted by said despreading unit,  
7 and calculates the calibration that cancels said quantity of  
8 distortion; and  
9 said phase calibration unit calibrates the receive signals  
10 based on said calibration.

1 5. The radio base station apparatus according to Claim 3,  
2 further comprising:

3           a power control unit that controls power of the probe signal  
4 generated by said probe signal generating unit and outputs the probe  
5 signal that has been subjected to the power control to said conversion  
6 unit.

1   6.       The radio base station apparatus according to Claim 2,  
2 wherein:

3           a spreading rate of said probe signal is larger than spreading  
4 rates of other communication signals.

1   7.       The radio base station apparatus according to Claim 1,  
2 wherein:

3           said probe signal is a sine wave.

1   8.       The radio base station apparatus according to Claim 1,  
2 further comprising:

3           an amplitude calibration calculation unit which calculates  
4 amplitude calibration required for calibrating amplitude of each  
5 receive signal based on the probe signal extracted by said probe  
6 signal extracting unit; and

7           an amplitude calibration unit which calibrates an amplitude  
8 of said each receive signal based on the amplitude calibration from  
9 said amplitude calibration calculation unit.

1   9.       The radio base station apparatus according to Claim 1,  
2 further comprising:

3           a transmit signal generating unit which generates a transmit  
4   signal;  
5           a transmit probe signal adding unit which adds a transmit  
6   probe signal to said transmit signal when said transmit signal  
7   generated by said transmit signal generating unit is supplied to said  
8   plurality of antenna elements;  
9           a transmit probe signal extracting unit which extracts said  
10   transmit probe signal from the transmit signal that is added with the  
11   transmit probe signal by said transmit probe signal adding unit;  
12           a transmit phase calibration calculation unit which calculates  
13   transmit phase calibration required for calibration of a phase of said  
14   transmit signal based on the transmit probe signal extracted by said  
15   transmit probe signal extracting unit; and  
16           a transmit phase calibration unit which calibrates the phase  
17   of said transmit signal based on the transmit phase calibration from  
18   said transmit phase calibration calculation unit.

1   10.    A radio base station apparatus provided with an array  
2   antenna having a plurality of antenna elements, wherein:  
3           a receive signal calibration system of said radio base station  
4   apparatus comprises:  
5           a receive probe signal spreading unit which spreads a specific  
6   code series with a specific spread code;  
7           a power control unit which performs power control on an  
8   output signal of said receive probe signal spreading unit;  
9           a D/A converting unit for the receive probe signal, for

10 converting an output signal of said power control unit from a digital  
11 signal to an analog signal;  
12 a probe signal RF unit which converts an output signal of said  
13 D/A converting unit to a radio frequency and performs power control  
14 on said radio frequency;  
15 a coupling unit which adds said probe signal to receive  
16 signals received respectively by said plurality of antenna elements,  
17 so as to generate receive signals added with probe;  
18 an RF unit which converts the receive signals added with  
19 probe, which are generated in said coupling unit, to baseband  
20 signals;  
21 an A/D converting unit which converts the baseband signals  
22 generated in said RF unit to digital signals;  
23 a receive probe signal despreading unit which outputs results  
24 of despreading the signals subjected to said A/D conversion with a  
25 spread code used for the probe signal, and which outputs results of  
26 despreading said signals intentionally with a spread code that has  
27 not been used;  
28 a correlation matrix calculation unit that obtains correlation  
29 of receive probe signals between each pair of antenna elements from  
30 the output of said receive probe signal despreading unit, calculates a  
31 signal subspace from an obtained correlation matrix, and calculates  
32 phase rotation and amplitude calibration required for an eigen vector  
33 having a maximum eigen value of the signal subspace and a  
34 predetermined vector to have a specific relation with each other; and  
35 a receive signal calibration unit which performs calibration of

36 the output signals of the A/D converting unit, with said output  
37 signals being converted from said baseband signals by the A/D  
38 converting unit, and with said calibration corresponding to said  
39 phase rotation and said amplitude calibration calculated by said  
40 correlation matrix calculation unit; and

41       said power control unit controls power of said probe signal  
42 inputted, such that the power becomes a necessity minimum required  
43 for said correlation matrix calculation unit to calculate the  
44 correlation matrix.

1   11.    The radio base station apparatus according to Claim 10,  
2   wherein:

3       said RF unit has a function of converting the signal subjected  
4 to the D/A conversion to a radio frequency and of inputting the  
5 converted radio frequency to each antenna element;

6       said coupling unit has a function of extracting a part of a  
7 transmit signal inputted to each antenna element; and

8       said probe signal RF unit has a function of converting a signal  
9 from said coupling unit to a baseband signal.

1   12.    The radio base station apparatus according to Claim 11,  
2   wherein:

3       a transmit signal calibration system of said radio base station  
4 apparatus comprises:

5       a transmit probe signal spreading unit which spreads a  
6 specific code series with a specific spread code;

7           a transmit signal calibration unit which calibrates a transmit  
8 signal generated in a modulation unit, using signals from said  
9 correlation matrix calculation unit;

10           a transmit signal combining unit which selectively adds an  
11 output signal of said transmit probe signal spreading unit, only to a  
12 signal to be transmitted from one antenna element out of transmit  
13 signals generated in said calibration unit, so as to generate transmit  
14 signals added with probe;

15           a D/A converting unit which converts an output of said  
16 transmit signal combining unit from digital signals to analog signals  
17 and for inputting said analog signals to said RF unit that converts  
18 the receive signals to the baseband signals;

19           an A/D converting unit for probe signal, for converting an  
20 analog signal to a digital signal, said analog signal being the  
21 baseband signal converted in said probe signal RF unit from the  
22 signal from said coupling unit; and

23           a transmit probe signal despreading unit which despreads an  
24 output of said A/D converting unit for probe signal with the spread  
25 code of the transmit probe signal, and for inputting the despread  
26 output to said correlation matrix calculation unit; and

27           said correlation matrix calculation unit obtains correlation of  
28 transmit probe signals between each pair of antenna elements from  
29 the output of the transmit probe signal despreading unit, and  
30 calculates phase rotation and amplitude calibration required for an  
31 eigen vector having a maximum eigen value of an obtained  
32 correlation matrix and a predetermined vector to have a specific

33 relation with each other, so as to control calibration by said  
34 calibration unit.

1 13. The radio base station apparatus according to Claim 12,  
2 wherein:  
3 said receive signal calibration system and said transmit  
4 signal calibration system use a same local oscillator as an oscillation  
5 source to perform up-conversion and down-conversion respectively,  
6 and use a same local oscillator as an oscillation source to perform  
7 timing generation.

1 14. The radio base station apparatus according to Claim 12,  
2 wherein:  
3 said transmit probe signal is not added selectively to a  
4 specific antenna element, but a signal using a different spread code  
5 for each antenna element is added to a signal of each antenna  
6 element.

1 15. The radio base station apparatus according to Claim 12,  
2 wherein:  
3 said receive signal calibration unit and a beam form unit for  
4 the array antenna are formed within a same unit, and said transmit  
5 signal calibration unit and a beam form unit for the array antenna  
6 are formed within a same unit.

1 16. The radio base station apparatus according to Claim 13,



2 wherein:

3       said transmit probe signal is not added selectively to a  
4 specific antenna element, but a signal using a different spread code  
5 for each antenna element is added to a signal of each antenna  
6 element.

1 17. An array antenna that comprises a plurality of antenna  
2 elements and is used for a radio base station apparatus, said array  
3 antenna further comprising:

4       a plurality of input-output terminals corresponding to the  
5 plurality of antenna elements;

6       auxiliary antenna elements, each of which is in weak  
7 conjunction with a part of a radiating element constituting each  
8 antenna element; and

9       input-output terminals for probe signal connected  
10 respectively to said auxiliary antenna elements.

1 18. The array antenna according to Claim 17, wherein:

2       instead of said auxiliary antenna element, each of which is in  
3 weak conjunction with a part of the radiating element constituting  
4 each antenna element, said array antenna comprises an auxiliary  
5 antenna element arranged in a position physically separated from  
6 said plurality of antenna elements, and said input-output terminals  
7 for probe signal are connected to said auxiliary antenna element.

1 19. The array antenna according to Claim 17, wherein:

- 2        said auxiliary antenna elements are provided within a
- 3    polygonal prism or a cylinder formed by said antenna elements.